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Sustainable urban freight systems and freight demand management

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Abstract

The paper defines the field of Freight Demand Management (FDM) and positions it in the broad range of public sector initiatives aimed at improving urban freight activity. To illustrate the magnitude of the impacts of FDM, the paper estimates the contributions to freight traffic by the various industry sectors in a sample of metropolitan areas, establishes the role of freight behavior research, and summarizes the performance of a number of FDM initiatives. The paper ends with a discussion of policy implications and conclusions.

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1. Introduction

The vast majority of the public sector initiatives that target urban freight aims at reducing its negative social and environmental impacts, which typically are the result of the freight vehicular activity. To this effect, transportation policy makers have enacted multiple initiatives that tend to focus on the physical infrastructure, the vehicular traffic, the vehicles, or the underlying logistical activity. This focus is a natural response to the involvement of freight vehicles in the generation of negative externalities.

However, on close inspection, research has revealed that the agent interactions at the core of supply chains play a fundamental role in shaping and generating the vehicle traffic that produces the undesirable effects (Holguín-Veras et

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al., 2015b). For instance, the freight traffic that produces congestion is the direct result of the delivery time decisions made by the receivers of supplies. Without receivers that demand their supplies during the peak traffic periods, the freight vehicles would not travel in congestion. If it were up to the carriers, they would travel in the least congested periods of the day. Truck idling is another example. This practice is routinely cited as a contributor to urban pollution and, as a result, a number of transportation agencies have enacted ordinance banning it. As in the previous case, the carriers have no incentive to idle, which is unproductive time. Quite frequently, trucks idle because the receivers are not ready to accept the shipments. Faced with the prospect of losing a customer for not making a delivery, or idling the truck to keep the cabin or the contents at a reasonable temperature, most carriers select the latter.

The key insight is that the roots of carrier behavior are frequently found in the decisions made by shippers and receivers. Central to this idea is the recognition that the participants in a supply chain are intrinsically linked by a common operational strategy, where the primary decisions are not always the carriers'. The agreement on a common operational strategy is essential to ensure the smooth transfer of the supplies that connect the dozens, and even hundreds, of production-consumption links that comprise modern production systems. At these links, a producer/shipper manufactures and ships the cargo that a receiver/consumer uses as an intermediate of final good. In between them, the carriers act as economic conduits that connect producers/shippers to receiver/consumers. The carriers' customers have a strong influence on how the deliveries are made.

From the standpoint of sustainability, the receivers play a critical role as they are the ones that generate the demand that, in turn, creates the traffic that produces the externalities. The receivers are a highly heterogeneous group that encompasses from small food vendors to large manufacturing sites in highly diverse industry sectors. As a result, the receivers exhibit great heterogeneity of operational practices and their responses to public policy. At the same time, the receivers are bound to play a key role in sustainability efforts because they: have the power to control how and when deliveries are made, are typically located where congestion is most acute, and are sensitive to public support for sustainable cities. Engaging receivers in the quest for sustainable cities is essential.

The main objective of this paper is to establish the rationale and potential of Freight Demand Management (FDM). To this effect, the authors position FDM within the broad range of public sector initiatives, discuss freight trip generation estimates to provide a clear picture of the contribution to congestion by the various industry segments found in urban areas, define the role that freight behavior research should play, discuss the experiences of a handful of FDM initiatives that have taken place, and identify the chief conclusions.

2. Overview of public sector initiatives

In this paper, the term *initiative* refers to the wide range of public sector interventions (e.g., strategy, program, project, policy) used to influence the urban freight system. As established by the authors (Holguín-Veras et al., 2014b, Holguín-Veras et al., 2014a) there is a wide range of initiatives that span the entire domain, from the supply to the demand side. A succinct discussion of the eight major groups follows.

Infrastructure management focuses on initiatives that improve freight facilities. This group includes construction and upgrade of ring roads to reduce the impacts of through-traffic, roads and intermodal terminals, freight clusters to relocate large freight generators, acceleration and deceleration lanes for trucks, the removal of geometric constraints at intersections, and building ramps for handcarts and forklifts. Large improvements tend to increase capacity in specific corridors, which primarily benefits large freight generators such as ports. Minor improvements seek to improve local conditions and alleviate congestion in specific corridors. In the case of the ramps for handcarts and forklifts, the initiative benefits the delivery activities serving small receivers (e.g., retailers, restaurants). Although increasing capacity may be necessary to ease traffic, the experience with passenger transportation shows that it may also induce demand.

Parking/loading areas management tries to improve the way in which the freight vehicles use urban spaces for pick-ups/deliveries. It includes the introduction of loading and parking restrictions, peak-hour clearways to increase the capacity of roads, vehicle parking reservation systems, the enhancement of building codes to handle current truck size, parking timeshare, upgrade of parking areas and loading docks, among others. Although these initiatives are generally beneficial, parking/loading management is not sufficient to solve all parking problems. There are cases where the parking supply is simply not sufficient to accommodate the demand from freight vehicles (Jaller et al.,

2013), and increasing parking supply is imperative.

Vehicle-related strategies use regulations to reduce the externalities produced by vehicles, e.g., by setting standards for emission and noise levels. Their implementation benefits local businesses and society, because they alleviate pollution and noise impacts, which makes commercial districts more attractive. These initiatives face the opposition from carriers, because the bulk of the financial burden for the upgrades is placed on them though incentives for adoption are sometimes provided. Since these initiatives do not decrease traffic, congestion and the pollution from other road users remain a concern.

Traffic management seeks to improve conditions using traffic engineering and control, such as vehicle size and weight restrictions, engine-related access restrictions, Low Emission Zones, time of day access restrictions, multi-use lanes, truck routes, dedicated truck lanes. These initiatives seek to improve mobility at the city level and at specific zones. Some of them face the opposition from carriers because they affect their routing efficiency. In particular, access restrictions have a high potential for unintended negative consequences.

Pricing, incentives, and taxation uses financial mechanisms to manage demand and minimize externalities. These initiatives use road and parking pricing to promote a better utilization of capacity and generate revenues, and recognition and certification programs to encourage adoption of sustainable practices and technologies. Road pricing is efficient for revenue generation but may not work well as a FDM tool, because the price signal not always reaches the agents that create the demand, i.e., the receivers. Incentives and taxation have a better chance of producing behavioral changes that foster sustainability.

Logistical management seeks to change the way in which supply chains take place by means of urban consolidation centers, Intelligent Transportation Systems, and innovative last-mile delivery practices, such as time slotting of pick-ups and deliveries at large traffic generators, driver training programs, anti-idling programs, and fostering use of delivery lockers. These initiatives, however, impose the burden of improving last mile logistics on carriers, neglecting the key role played by the receivers. This lack of involvement of receivers hampers their efficiency in reducing traffic and its impacts.

Freight demand and land-use management initiatives alter the demand for freight to enhance sustainability and efficiency. Land use management includes the relocation of large traffic generators, and the integration of freight into the land use planning process. FDM attempts to decrease the impacts produced by deliveries, by retiming them to the less congested hours of the day, by consolidating delivery trips, or by coordinating deliveries from different establishments. These initiatives benefit the whole metropolitan area because they reduce the total amount of freight traffic, particularly, in the peak hours. These initiatives target the industry sectors that generate the bulk of freight traffic.

The authors' experience clearly indicates that the public sector initiatives that have been implemented most frequently are the ones related to management of infrastructure, traffic, and parking and loading areas. It is likely that their popularity stems from the fact that these fields are familiar to transportation planners and engineers. Initiatives in logistical management are less frequently used and, by far, FDM initiatives are the least used. This is ironic because FDM is probably the field with the largest potential to achieve the large impacts in traffic reduction needed to mitigate the negative impacts of climate change.

FDM is "*the area of transportation policy that seeks to influence the demand generator—to achieve urban freight systems that increase economic productivity and efficiency; and enhance sustainability, quality of life, and environmental justice.*" It is the counterpart of the passenger demand management. Designing and implementing effective FDM programs requires the identification and selection of: (1) the industry sector(s) that would be the target of the policy; (2) the policy instrument to be used to induce the desired behavior change; and (3) a suitable implementation strategy. The selection of these elements should be made on the basis of the potential payoff, e.g., number of truck trips that could change from the current to the desired behavior. It is important to get a good idea about the magnitude of freight activity by industry sector, and the willingness of these sectors to change behavior in response to public policy. Freight trip generation analyses could provide estimates about the former, while freight behavior research could do the same for the latter. These aspects are discussed next.

3. Contribution to congestion by industry sectors

Providing solid information about the contributions to freight traffic by the different industry sectors is important because it helps decision makers, transportation planners, and citizens to understand the causes of urban congestion. This is essential to the design of FDM schemes. For FDM to have maximum impact, it has to target the industry sectors that offer the highest payoff in terms of total improvements. To illustrate the kind of results that could be expected, the authors estimated the breakdown of the freight traffic generated by industry segments for a sample of metropolitan areas in the United States.

Urban economies are complex milieus of numerous economic activities that serve the needs of their customers. Broadly speaking, these activities could be classified into *freight-intensive* (FIS) and *non-freight intensive* economic sectors (non-FIS). The former represents the sectors where production or consumption of freight is the primary activity, and typically account for 40% to 60% of the total employment and 40% to 50% of the number of establishments; while the latter are those sectors where use of freight is incidental. It should be mentioned that, although the non-FIS have relatively low freight trip generation rates, they create large amounts of freight traffic on account of their number of establishments. Table 1 contains the list of industry sectors in both groups classified using the North American Industrial Classification Codes (NAICS).

Table 1. North American Industry Classification System (NAICS) Description

NAICS	Freight-intensive Sectors	NAICS	Non-freight-intensive Sectors
1	Agriculture, Forestry, Fishing, Hunting	51	Information
21	Mining, Quarrying, Oil / Gas Extraction	52	Finance and Insurance
22	Utilities	53	Real Estate and Rental and Leasing
23	Construction	54	Professional, Scientific, Tech. Services
31-33	Manufacturing	55	Management of Companies / Enterprises
42	Wholesale Trade	56	Administrative, Support, Waste Manag.
44-45	Retail Trade	61	Educational Services
48-49	Transportation and Warehousing	62	Health Care and Social Assistance
72	Accommodation and Food Services	71	Arts, Entertainment, and Recreation
		81	Other Services (except Public Admin.)
		92	Public Administration

The metropolitan areas considered for the freight trip generation analyses were selected from the official list of Metropolitan Statistical Areas (MSAs) in the United States (United States Census Bureau, 2013) on the basis of their size. The MSAs represent the largest (New York City-Northern New Jersey-Long Island), the third quartile (Palm Bay-Melbourne-Titusville, Florida), the median (Fargo, North Dakota-Montana), and the first quartile (Lebanon, Pennsylvania). The authors used the ZIP Code Business Pattern Data (U.S. Census Bureau, 2011) to compute the freight trip generation using the models estimated by the authors (Holguín-Veras et al., 2012, Holguín-Veras et al., 2013, Holguín-Veras et al., 2011a, Sánchez-Díaz et al., 2014). The results are shown in Table 2. Figure 1 shows the breakdown of freight trip generation by business size.

Table 2. Freight Trip Generation by Industry Sectors (2012)

NAICS	Description	NY-Northern NJ-Long Island	Palm Bay- Melbourne- Titusville, FL	Fargo, ND- MN	Lebanon, PA
44	Retail trade	39.06%	44.19%	34.85%	37.50%
42	Wholesale Trade	19.41%	11.04%	17.89%	13.57%
72	Accommodation / Food Services	15.72%	16.87%	13.97%	14.35%
23	Construction	11.47%	14.35%	16.14%	12.18%
31	Manufacturing	8.17%	8.80%	8.11%	15.35%
48	Transportation / Warehousing	6.16%	4.74%	9.03%	7.05%
Total freight trip generation (FTG) for FIS		1,024,477	25,682	15,515	10,285

Population	19,949,502	550,823	223,490	135,486
Number of establishments (Total)	545,197	13,597	6,709	4,272
Number of establishments (FIS)	235,325	5,893	3,317	2,185
Employment (Total)	7,568,043	172,925	119,626	79,543
Employment (FIS)	3,061,899	84,821	63,186	47,164
Establishments (FIS)/1000 persons	11.796	10.699	14.842	16.127
Employment (FIS)/1000 persons	153.482	153.990	282.724	348.110
FTG/1000 employees (all sectors)	135.369	148.517	129.698	129.302
FTG/1000 employees (FIS)	334.589	302.783	245.549	218.071
FTG/1000 persons	51.354	46.625	69.423	75.913
Average FTG per establishment	4.353	4.358	4.677	4.707
Average employment per establishment	13.011	14.394	19.049	21.585

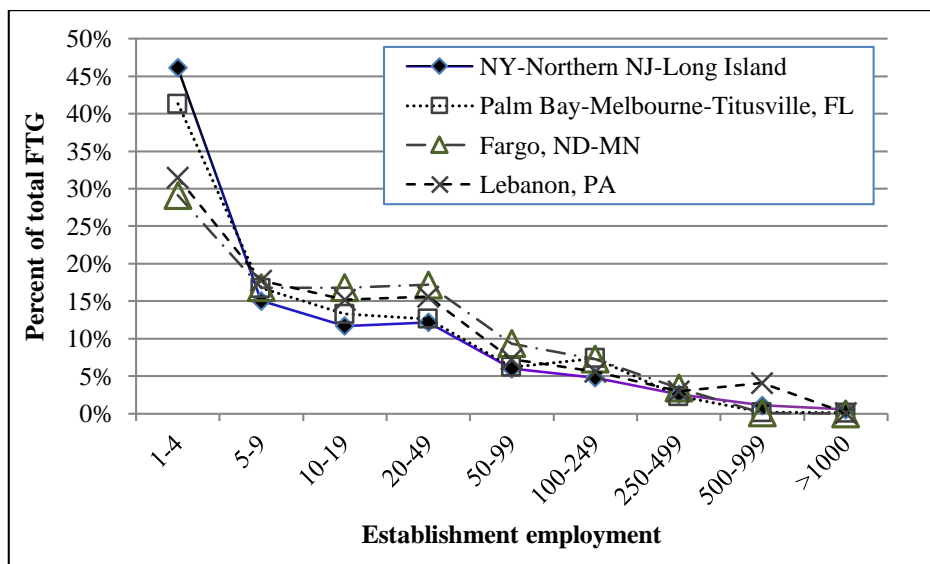


Fig. 1. Distribution of FTG by Establishment Size

The results show the predominance of the retail sector as the largest contributor to FTG, with a share of 35% to 44% of the total FTG. Not surprisingly, the largest share is in Palm Bay, a tourist town in Florida. Wholesale Trade, Accommodations and Food Services, and Construction compete for the next three positions. The table also shows a number of indicators that measure the intensity of the activity at the various MSAs. Figure 1 shows the breakdown of the total FTG by business size. The most remarkable finding is the large role played by establishments of less than nine employees that contribute between 45% to 60% of the total FTG, which clearly shows that the generation of freight traffic is spread out across the entire metropolitan area.

4. Role of freight behavior research

Influencing freight demand for the better requires a solid understanding of how the various industry sectors involved in urban freight activity would respond to policy. Using freight behavior research to answer these questions is critical because, generally speaking, it is very difficult for outsiders to correctly guess how the private sector would

respond. The main reason is the heterogeneity of behaviors, which stems from the vast differences in economic activities performed, company size, industry structure, and market power.

Freight behavior research could be either qualitative or quantitative in nature. Although seeking similar objectives, these branches differ in the style of the investigative process, the tools used, and the results produced. Qualitative techniques—such as in-depth-interviews or focus groups—seek to gain a general understanding of the factors that explain decision making behavior. In contrast, quantitative techniques try to produce numerical estimates of the behavioral changes expected in response to a policy stimulus. Examples include stated and revealed preference surveys, and discrete choice modeling.

Qualitative and quantitative behavioral research techniques are best seen as complementary approaches that contribute different perspectives to the study of complex systems. Qualitative techniques are frequently used to study complex unstructured systems and as a precursor to quantitative investigations. If conducted by competent professionals, qualitative and quantitative research should provide consistent results. The research conducted by Holguín-Veras et al. (2015a) found that qualitative research was able to correctly identify about 78%-86% of the findings that subsequent quantitative research found (though quantitative research always added details). The number of erroneous conclusions was relatively low, as 14-22% of the findings were partially or totally rejected.

The main role of freight behavior research is to gain insight into how the private sector—and specific industry sectors—would respond to a given policy. Identifying the likely response by industry sectors is crucial because it helps focus outreach and implementation efforts on specific targets, and eliminates the possibility of wasting resources on sectors that would not react in the desired manner. In cases where numerical estimates are desired, a combination of qualitative and quantitative techniques is typically the best option. In these cases, in-depth-interviews and focus groups could be used to gain general knowledge about the constraints faced by the various agents involved in supply chains, the factors they take into account for decision making, and to help design questionnaires and other forms of quantitative research. The second stage could involve conducting interviews to collect stated and revealed preference data, which may be used to estimate behavioral discrete choice models and elasticities of choice.

If numerical estimates are not required, in-depth-interviews and focus groups could indeed provide a solid idea about the effectiveness of a given initiative. However, there are caveats. Due to the heterogeneity of industry behaviors, great care must be taken to ensure that the data collected by qualitative research techniques represent the wide range of potential behavioral responses. To this effect, it is important to collect information from the key industry sectors and from establishment of different sizes. It is entirely possible, and highly desirable in some cases, to conduct a second round of in-depth-interviews and focus groups targeting specific sectors or sub-sectors. This extra effort may be a worthy investment as it may contribute towards a more effective policy design, and to avoid the negative impacts of a poorly designed public sector initiative that will erode public trust and confidence.

5. Freight demand management: experiences and potential

FDM includes a wide range of initiatives, including voluntary off-hour delivery programs, staggered pick-up/delivery programs, receiver-led consolidation programs. The cases discussed are the off-hour delivery programs implemented in New York City (NYC) and at the Ports of Los Angeles and Long Beach (POLALB), Receiver-Led Consolidation programs, and the FDM program implemented during the London Olympic Games. Although the number of actual and documented experiences in FDM is small, the cases included here provide a broad view of the field. The OHD program in NYC is an example of the use of incentives to induce receivers to change behavior, the PierPass program at the POLALB is an instance of receiver pricing, the FDM program during the Olympic Games exemplifies an application to special events, while Receiver-Led Consolidation illustrates the type of approaches that could be enacted by regulatory approaches to foster consolidation.

5.1. The off-hour delivery program in NYC

The objective of Off-Hour Delivery (OHD) programs is to shift deliveries from the regular business hours, to the off-hours, i.e., from 7 PM to 6 AM. As shown by Yannis et al. (2006) and Holguín-Veras et al. (2011b), OHD programs increases economic welfare by decreasing congestion and travel times for all users, diminishing environmental impacts, and improving reliability of deliveries. Although OHD programs tend to have the support from carriers

because delivering during off-hour significantly increase productivity, they tend to be opposed by the receivers, who are concerned about higher staffing costs and risks. As in most markets receivers have more market power than carriers and suppliers, the delivery ends up being scheduled at the receivers' will, which is often during business hours and highly congested hours. This opposition of receivers can be overcome with well-designed public sector incentives (e.g., financial, recognition) and strong stakeholder engagement.

OHD could be conducted with or without the staff of the receiving establishment present, leading to the two main modalities of: staffed OHD and unassisted OHD. A great deal of research has been conducted showing that the use of incentives induce receivers to change behavior, i.e., take the step and accept OHD and the associated risks. For instance, Holguín-Veras et al. (2007) and Domínguez et al. (2012) found that an on-going financial incentive fosters receivers' participation in OHD and that the propensity to participate depends on the industry sector and other attributes of the receiver. Unassisted OHD are an appealing alternative, as they do not entail additional staff costs, but receivers continue receiving the benefits from OHD. In the case of unassisted OHD, a one-time-incentive can be sufficient to induce a permanent shift. For instance, Holguín-Veras et al. (2015c) found that a one-time-incentive, discounts from carriers, business support services and public recognition provided to participants are effective incentives to foster unassisted OHD.

The OHD program was successfully launched in NYC as a collaboration between the Rensselaer Polytechnic Institute (RPI) and the NYC Department of Transportation (NYCDOT). The OHD program has gained the enthusiastic support of the private sector, which is cooperating in its implementation. Leading partners include: Manhattan Chamber of Commerce, New York State Motor Truck Association, New Jersey Motor Truck Association, SYSCO, Whole Foods, Wakefern, Duane Reade, Waldorf-Astoria, Beverage Works, among others. More than 400 commercial establishments in Manhattan have already switched to the off-hours. The project has wide ranging potential impacts on the economy, environment, and the quality of life in urban areas. By removing the interferences produced by deliveries, OHD programs facilitate the implementation of other sustainability initiatives, such as bus rapid transit systems, bike lanes, and enhanced pedestrian walkways that also need curb space. Most of all, the OHD project has dramatically confirmed the potential of public-private sector and academic cooperation in solving urban congestion.

Once fully funded, it is estimated that the OHD program will produce large economic impacts. A 20% shift to OHD would produce economic savings of \$100-\$200/million per year to carriers, shippers and receivers; and pollution savings of: 202.7 metric tons (t)/year of CO; 40t/year of HC; 11.8t/year of NO_x; and 69.9 kg/year of PM₁₀ (Holguín-Veras et al., 2011b). These impacts are the congestion and pollution savings accrued by all of the regular-hour travelers. On a per-capita basis, each receiver that agrees to OHD would be responsible for a reduction of about 551 vehicle-miles traveled, and 195 vehicle-hours traveled, and a reduction in CO of 12 kg. The reductions in pollution produced by the trucks making OHD are significant. Using GPS data collected from the participating companies, the team computed fuel consumption and emissions using the Comprehensive Modal Emission Model (CMEM) (Barth et al., 2000) for a sample of network segments used in both regular day deliveries and OHD. The results show that the average fuel consumption rate and total emission rates during the off-hours are significantly lower than those during regular hours for the same segment. The differences are generally larger than 20% for highway and toll road segments, and larger than 50% for urban arterial road segments.

In term of the financial impacts on carriers, it is estimated that for every delivery tour that switch from regular to the off hours carriers save, on average \$42,500/year. The parking fines in New York City average about \$750/truck-month. Since it is easier for truckers to find legal parking spaces near their delivery locations during off hours, every OHD route that replaces a regular hour route saves about \$9,000/year in parking fines. Essentially, the total savings to carriers amounts to about \$51,500/year.

The OHD program is sustainable on all fronts. Economically, by removing the market failure (the receivers' reluctance to accept OHD) that restricts OHD from taking place naturally, the program allows entire supply chains to switch to their most efficient outcome. The ensuing increases in productivity enhance the economic competitiveness of congested urban areas, reducing the cost of doing business for receivers and the carriers. The program allows for lasting, sustainable economic shifts through entire supply chains, and the resultant potential for realizing sustainability goals. The OHD program is a win-win solution that benefits carriers, receivers, and urban communities at all hours, enhancing quality of life, economic development, and environmental sustainability.

5.2. *The off-peak program at the Ports of Los Angeles and Long Beach*

The Ports of Los Angeles and Long Beach are the busiest port complex in the United States (US). In 2005, these ports moved more than 14 million twenty-foot equivalent units (TEU), representing 34% of the total container traffic in the US, attracting more than 35,000 daily truck trips, and generating significant amounts of externalities. These externalities have been a concern for the State of California, who initially tried to tackle the problem through new legislation. In August 2002, the State of California passed the California Assembly Bill 2650 (AB 2650), which imposed a fee (\$250) on terminal operators for every truck waiting more than 30 minutes to enter the terminal. The AB 2650 did not improve operational conditions at the ports. It exposed the difficulties of imposing regulations on organizations with substantial economic power, and showed the need for alternative initiatives with more participation from the terminal operators (Giuliano and O'Brien, 2007). In 2005, the marine terminal operators decided to create PierPASS Inc. to address multi-terminal concerns such as congestion, security and pollution. Giuliano and O'Brien (2008) identified the growth of international trade, public awareness of the negative externalities produced by the ports' operations, capacity constraints, and legislative pressure, as the key factors leading to the creation of PierPASS.

One of the first initiatives implemented by PierPASS was the OffPeak program which aimed at shifting cargo movements to the less congested period of the day, i.e., from 6PM to 3AM, and to the weekends. To this effect, PierPASS imposed a \$40 fee per twenty-foot-equivalent (TEU) transported during peak hours to the receiver of the cargo; the fee was then increased to \$50 per TEU in April 2006. It is noteworthy that the cargo already charged with the Alameda Corridor fee or being transshipped to other ports, as well as empty container returns, or domestic freight were not charged the fee.

The OffPeak program was successful in shifting truck traffic from the peak hours to the off-hours, reaching in the first weeks of implementation the goal for the end of the second year (i.e., 35% traffic diverted). By December 2005, one million trucks were operating during off-hours, and by June 2006 this number reached the 2 million (PierPASS, 2007). By September 2014, the port was handling about 17,000 truck trips on a typical night (i.e., 55% of traffic), and the program completed 30 million truck trips handled during off-hours since its inception (PierPASS, 2014). The program's impact on off-hour traffic remains unclear, because no data measuring off-hour operations before the launch of OffPeak are available. Based on interviews, Giuliano and O'Brien (2008) estimated that about 20% of containers were being transported in the off-hours before 2005, suggesting that the additional 15% observed by the end of 2005 was the result of the OffPeak program.

5.3. *The London Olympic Games*

Hosting the 2012 Olympic Games posed significant challenges to London in terms of changes to the use of the road network. In order to achieve the rapid transport of 80,000 athletes, officials, sponsors and the media to the London 2012 sites an Olympic / Paralympic Route Network (ORN / PRN) was put in place across London's road network. The ORN totaled 105 miles in London and was in force from July to September 2012. The measures used on the ORN / PRN included the prevention of right turns, side road closures, changes to traffic lights and pedestrian crossings, adjustments to bus and coach stops and the temporary suspension of bus stops. There were also additional parking restrictions and road closures around the sites. Stopping on the ORN / PRN was only permitted between midnight and 06:00. Taken together these restrictions were considered to be potentially challenging to London businesses.

The Olympic Delivery Authority (ODA) suggested in 2010 that the transport arrangements necessary for the Games would have a negative impact on freight activity in the rest of London (Olympic Delivery Authority, 2010). The Freight Transport Association expected traffic restrictions put in place for the Olympics to cause three types of disruption for non-Games road freight transport in London: i) journey time unreliability arising from the reduction in road space and transfer of traffic onto other routes, ii) difficulties accessing specific roads that are either closed or subject to banned right turns, and iii) difficulty stopping on-street to load and unload as curbside access would be affected by the restrictions (Freight Transport Association, 2011).

In this context, the ODA and Transport for London (TfL) produced guidance for businesses, suggesting ways to alter their freight and logistics systems to avoid problems (Olympic Delivery Authority, 2010). Their advice to businesses receiving and sending goods, and carrying out servicing activity was to consider the so-called '4Rs': namely reducing activity, re-timing activity, re-routing activity, and revising the transport mode used where possible.

Specific solutions put forward included: receiving and collecting goods at less busy times and on less busy days, assessing whether fewer goods could be received during the Games, and reviewing which deliveries were essential; stockpiling non-perishable goods in advance, sharing resources and deliveries with other local businesses, changing the delivery point of the supplies, and planning alternative routes to avoid congestion hotspots. TfL worked closely with businesses and other organizations likely to be affected by the road restrictions during the Games to develop action plans to address these issues (Transport for London, 2011). The actions that companies could take to mitigate the Games road restrictions mainly fell into two broad categories: (1) Increasing the grouping of freight transport (e.g., through measures such as ordering less frequently, sharing deliveries with neighboring businesses, using urban consolidation centers); and (2) Changing the time at which freight transport activities take place to when the ORN restrictions are not in force.

Actions taken to increase the grouping of freight transport would be expected to increase vehicle load factors and reduce vehicle empty running, thereby leading to reductions in the vehicle hours and kilometers travelled. Actions taken to shift the times at which freight transport takes place to the off-peak/night would be expected to lead to faster vehicle speeds for these off-peak journeys, and hence also reduce total vehicle hours.

Freight industry actions and experiences during the Games

Large scale telephone surveys with businesses and freight operators were carried out by TfL to establish the extent of changes in behavior and the response to the '4Rs.' Of the '4Rs' (i.e. reducing activity, re-timing activity, re-routing activity, and revising the transport mode) that businesses were encouraged to consider implementing to cope with the Games, the survey work shows that 'Reduce' and 'Re-time' options proved the most popular (with 45-50% of respondents taking initiatives in these areas), followed by 'Re-route' (with about 40% of freight operators and 25% of businesses adopting initiatives in this area), while the least popular were options around revising the mode of transport (with only 5% changing the mode used) (Transport for London, 2012).

The most popular 'Reduce' measures adopted by businesses and freight operators (in order of importance with the most adopted first) included: ensuring that deliveries were right first time, postponing non-essential deliveries, stockpiling, consolidating journeys, staff taking leave, staff working from home, sharing resources, and operating a temporary stockroom. The most popular 'Re-time' measures adopted included: changing delivery and collection times, pre-ordering and pre-delivery of goods, changing staff starting times or shifts, and running out of hours operations. 'Re-route' measures adopted included: avoiding congestion hotspots, avoiding traffic management restrictions, and the use of alternative locations. 'Revise mode' measures adopted included: walking, cycling, and river-based deliveries (Transport for London, 2012).

A survey by the London Chamber of Commerce found that 51 per cent of respondents made changes to help avoid delivery disruptions during the Games. The results showed that "24 per cent of respondents postponed non-essential orders, 19 per cent used alternative delivery methods, 18 per cent had deliveries at different times, 13 per cent used alternative suppliers and 15 per cent ordered larger quantities in a smaller number of deliveries" (London Chamber of Commerce and Industry, 2012).

Research carried out by TfL into freight traffic volumes indicates changes in the time of goods vehicle operations in London as a whole, the data suggests a shift towards a greater proportion of light trucks journeys being made overnight. However, there appears to have been no relative reduction in van traffic in the morning peak period. For heavy trucks the data indicates substantial relative increases in journeys made overnight, together with reductions in the proportion of lorry traffic across the working day. In Central London, these changes in the time of goods vehicle operations during the Olympics were even more marked than in London as a whole for both light and heavy with greater relative use during the night, and less relative use during the day than in 2011 (Transport for London, 2012).

5.4. Receiver-led consolidation programs

Receiver-Led Consolidation (RLC) programs are another type of FDM initiative. These programs encourage receivers to reduce the number of deliveries they receive. This reduction can be achieved via reducing the number of suppliers through coordination with other receivers (e.g., inside the same building, inside the mall), or using their power to foster the consolidation of cargo from multiple suppliers (e.g., in staging areas, in micro-terminals). The main benefits from RLC are the reduction in the interruptions produced by deliveries, the increase in productivity for

suppliers, and the reduced delivery traffic that benefits the city at large. RLC programs have been implemented in different ways, such as, through Delivery and Servicing Plans and Urban Staging Areas.

The concept of a Delivery and Servicing Plan (DSP) was developed and pioneered by Transport for London (Transport for London, 2013a). DSPs are intended to provide a framework to better manage all types of freight vehicle movement to and from individual buildings including retail shops, offices, hotels, restaurants factories, or distribution centers. DSPs were developed in London building on the experience of travel plans for businesses (dealing with the movement of people). A DSP is drawn up by a business after an initial review of current deliveries received. Among the initiatives that can be applied with a DSP are: reducing the number of suppliers, grouping the deliveries of the supplier(s), reducing the number of deliveries per week, ordering less frequently, and purchase collaboratively with other businesses. Businesses can identify suppliers delivering or providing similar services, and negotiate with only one of them to serve all the clients in the building. The supplier selected will transport larger quantities of supplies in the same vehicle trip, decreasing the overall delivery traffic generated by the building. The negotiation process also provides receivers with an opportunity to get discounts from their suppliers. RLC encourage receivers to use their market power to reduce the number of deliveries attracted, foster consolidation, and by this means reduce delivery traffic. Implementing a DSP is recommended but optional for existing businesses and establishments. However, in accordance with the London Plan, all referable planning applications (i.e., Large-scale development, Major infrastructure, and Development which may affect strategic policies) should be accompanied by a Construction Logistics Plan (CLP) and a DSP.

The research for London and for New York City reveals the large potential of RLC programs. The implementation of Delivery Servicing Plans in London led to significant reductions for different types of receivers. Some successful case studies include the reduction by 20% in the total number of deliveries arriving at the Palestra Building (home of the TfL's Surface Transport Directorates) via centralization of storage and supplies orders (Transport for London, 2013b); the experience with Almo, managing office supplies, which showed a reduction in deliveries by two-thirds via consolidation (along with off-hour deliveries); and the Emirates stadium which managed to reduce deliveries and save costs via consolidation, i.e., by switching its milk and dairy supplier so that all dairy products were delivered along with other catering supplies (Transport for London, 2013a).

In the case of New York City, the research of Holguín-Veras and Sánchez-Díaz (2015) estimated the potential delivery traffic reductions that could be brought by RLC. The authors collected data from 231 receivers, and inquired about their interest in asking their suppliers to consolidate deliveries. The results were used to estimate a discrete choice model and assess the potential participation in RLC. The sectors more inclined to participate were retail, accommodation, and wholesale. Small establishments tended to be less interested in the consolidation, except for the case of food and beverage stores, where the propensity to participate increases with the number of deliveries. The results from the discrete choice model, combined with freight trip generation analyses, showed that RLC could lead to reductions in the range of 3.0% and 8.8% of the total delivery traffic in the NYC metropolitan area, and between 3.5% and 11.2% in Manhattan, with the largest reductions expected in Midtown and Lower Manhattan, in Queens, and in West Brooklyn. The application of a Behavioral Micro-Simulation to Manhattan estimated the total savings for carriers to range between \$376,906 and \$1,186,128 per day, as a result of the 4,740 to 15,062 hours saved in operations. The expected savings in vehicle miles traveled range from 33,445 to 104,255. In addition to the savings for the carriers participating in RLD, the expected reduction in truck traffic between 6.49% and 14.10% in Manhattan is expected to generate between \$57.10 and \$84.42 million per year in economic benefits (Holguín-Veras and Sánchez-Díaz, 2015).

The magnitude of these traffic reductions suggests that the public sector should consider RLC programs as part of their sustainability efforts. In order to implement RLC programs and achieve these savings, public sector incentives, monetary or not, may be needed to spur receivers into action. Otherwise, inertia and the natural tendency to only change when forced by the circumstances will lead receivers to continue in the status quo.

6. Policy implications and concluding remarks

As discussed throughout the paper, FDM has tremendous potential to influence large segments of the receivers of deliveries and, ultimately, freight traffic. The magnitude of the potential reductions are significant. The OHD project is estimated to be able to switch between 20% to 40% of the deliveries in the retail and accommodation and food sectors to the off-hours. As of February 2015, more than 400 restaurants (about 4% of the sector) have switched to the

off-hours in response to the incentives provided by the research project discussed in the paper. A fully funded implementation is likely to increase these numbers significantly. The PierPass project has succeeded in switching more than 35% of the containers from the Port of Los Angeles and Long Beach to the off-hours, using receiver pricing. The research on RLC and the very limited experiences on the subject are equally encouraging: about 20% of receivers in Manhattan indicated that they could reduce the number of deliveries that they receive; while a pilot test in London reported reductions of freight traffic of about 20%. The magnitude of these impacts clearly exceed the effects of the other public sector initiatives that have been tried at various cities in the world. Moreover, the potential benefits of FDM and its business-friendly nature suggest that FDM initiatives could be both impactful and relatively easy to implement. However, there are challenges to be overcome.

The first challenge is related to finding out what is the best way to induce the desired behavioral changes on the part of the receivers. This necessitates the assistance of freight behavior research to determine, among others: what industry sectors are most inclined to respond to public sector policy in the manner desired? what kind of policy levers should the public sector use? what should be the magnitude of these policy levers? The second challenge is how best to engage the private sector in the effort? As the experience of the OHD project clearly indicates—even when a company had already committed to participate in the program—it took them a while to find the time to take the step. In brutally competitive environments, it is difficult for the private sector to take time out to enact changes in their operations. The public sector must be patient and mindful of the importance of gently pushing the private sector towards changing their practices. Business associations, Business Improvement Districts, and industry leaders could play a key role by providing guidance, examples to follow, and assurances about the overall benefits of the FDM efforts. A third challenge is institutional in nature. In most cases, city agencies have jurisdiction over different aspects of the urban economy. Public roads and traffic control are typically the responsibility of a city department of transportation; mass transit is routinely assigned to a transit agency; while land use, economic development, and even finance/tax agencies regulate the commercial activities performed by commercial establishments. Since the latter type of agency is the one with inheritance on the receiver of supplies, inter-agency cooperation is needed to ensure FDM initiatives succeed. However, this could be a challenge because these agencies—the ones with the power to influence the behavior of receivers by means of incentives, pricing, taxation, and the power of licensing—may not understand, or agree, that they have a role to play in using these powers to foster changes in supply chains. The private sector and community leaders—intrinsically interested in the implementation of initiatives that increase quality of life and economic conditions—could play a key role in pushing for an appropriate level of inter-agency cooperation.

In spite of these challenges, however, there shall be no doubt about the importance of successful implementation of FDM. The potential benefits of holistic FDM initiatives are such that more than justify overcoming the challenges already identified. After all, FDM may hold the key to new paradigms of urban freight systems that improve economic productivity and efficiency; and enhance environmental sustainability, quality of life, and environmental justice. Achieving this lofty goal is worth the effort.

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